

Correlating the Solar Wind and Coronal Holes from Different Viewpoints

WHPI Workshop, September 13-17, 2021

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Impact on Earth of Solar Activity in WHPI Solar Minimum (2018-2020)

Coronal Mass Ejections (CMEs):

Max Dst -65 nT and max ap of 94 nT (linearized Kp of 6+) on May 14, 2019

High-Speed Streams (HSS) of solar wind:

(1) Nov 2018 – Mar 2019, 9-day recurring HSS (CR2211-2214)

(2) Jul-Nov 2019 with 27-day recurring HSS with min and max in CR2219-2224:

Dst -32, -53, -52, -49, -46, -28 nT on Jul 10, Aug 5, Sep 1, Sep 27, Oct 25, Nov 23

ap 48, 56, 56, 56, 56, 27 nT on 191, 217, 244, 270, 298, 327 day#

Kp 5, 5+, 5+, 5+, 5+, 4

We will examine HSS from the sun from 3 different viewpoints: Earth, STEREO-A, and Mars (1.5AU), and trace them back to the coronal holes (CHs) on the sun using a Potential Field Source Surface (PFSS) model of Marc DeRosa and colleagues from the Lockheed Martin Solar and Astrophysics Laboratory (LMSAL) in California.

Radial solar wind velocity from the sun to 5.5au on November 23, 2019 for CR2223 HSS

2019-11-23T14:00

Using ENLIL Model

2019-10-27T07 +27.28 days

Mars

Earth Jupiter Mars Mercury Venus Dawn OSIRIS-REx ParkerSP
Spitzer Stereo_A Stereo_B

Ecliptic Plane

W90 21 LAT = -0.8°

19 20

18 22

17 23

16 24

15 25

14 26

13 27

12 28

11 29

10 30

9 31

8 32

7 33

6 34

5 35

4 36

3 37

2 38

1 39

0 40

E90

Earth

STEREO-A

V_r (km/s) 200 550 900 1250 1600

N90 LON = 0°

W180

R = 1.0 AU

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90°

180°

270°

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McIntosh Style Coronal Hole (SDO/AIA) Synoptic Map

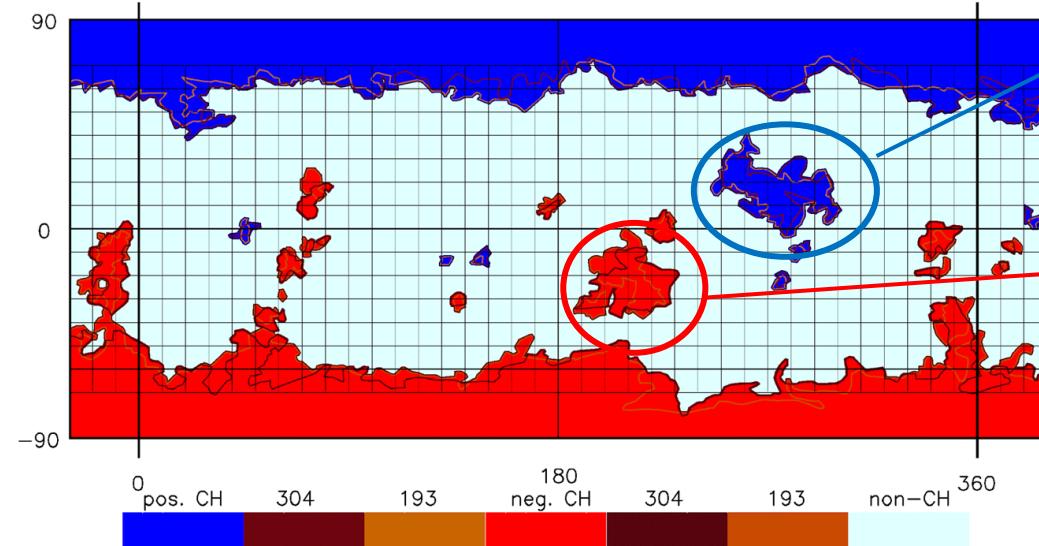
End date (longitude=0): 2019-11-12T17:46:11

B angle end date 3.170

CR2223we

Start date (longitude=360): 2019-10-16T10:34:43

B angle start date 5.800



Second biggest Northern (N) CH area of positive polarity in WHPI, preferred longitude $\sim 270^\circ$, moves prograde.

Largest Southern (S) CH area of negative polarity in WHPI, Preferred longitude $\sim 200^\circ$, stationary ($\sim 25\text{--}29^\circ\text{S}$) plus 2 weaker longitudes.

McIntosh Style Coronal Hole (STEREO-A) Synoptic Map

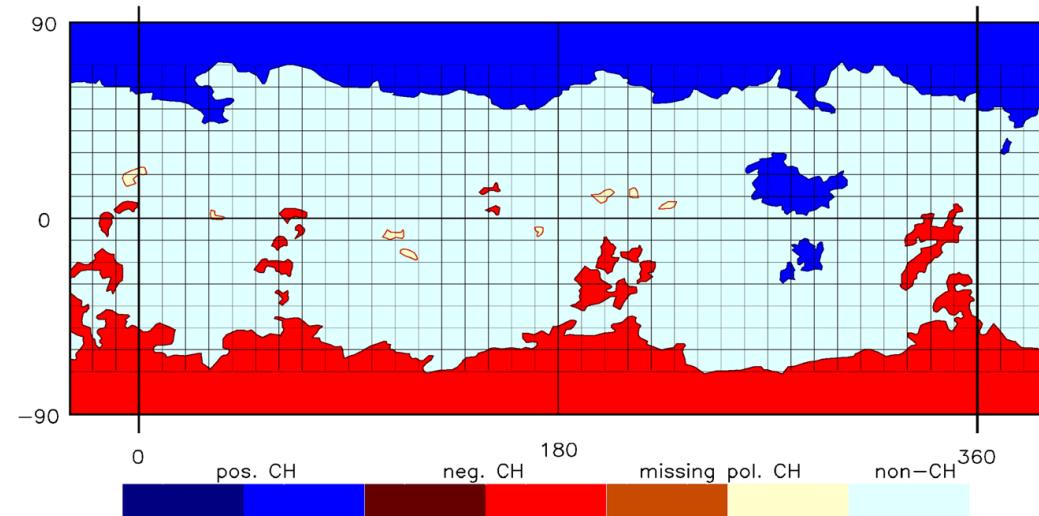
End date (longitude=0): 2019-11-06T13:50:47

B angle end date 6.800

CR2223wa

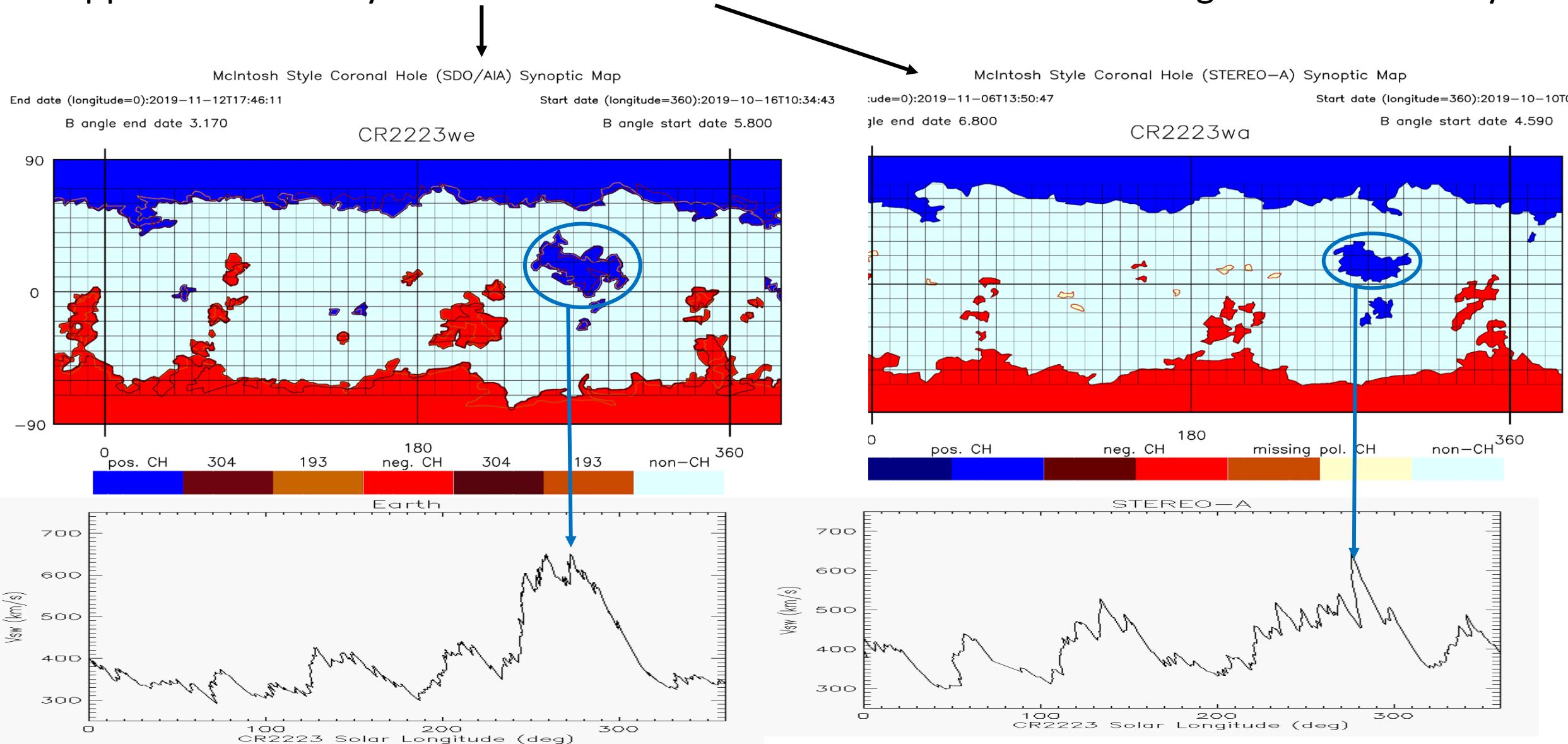
Start date (longitude=360): 2019-10-10T03:33:48

B angle start date 4.590

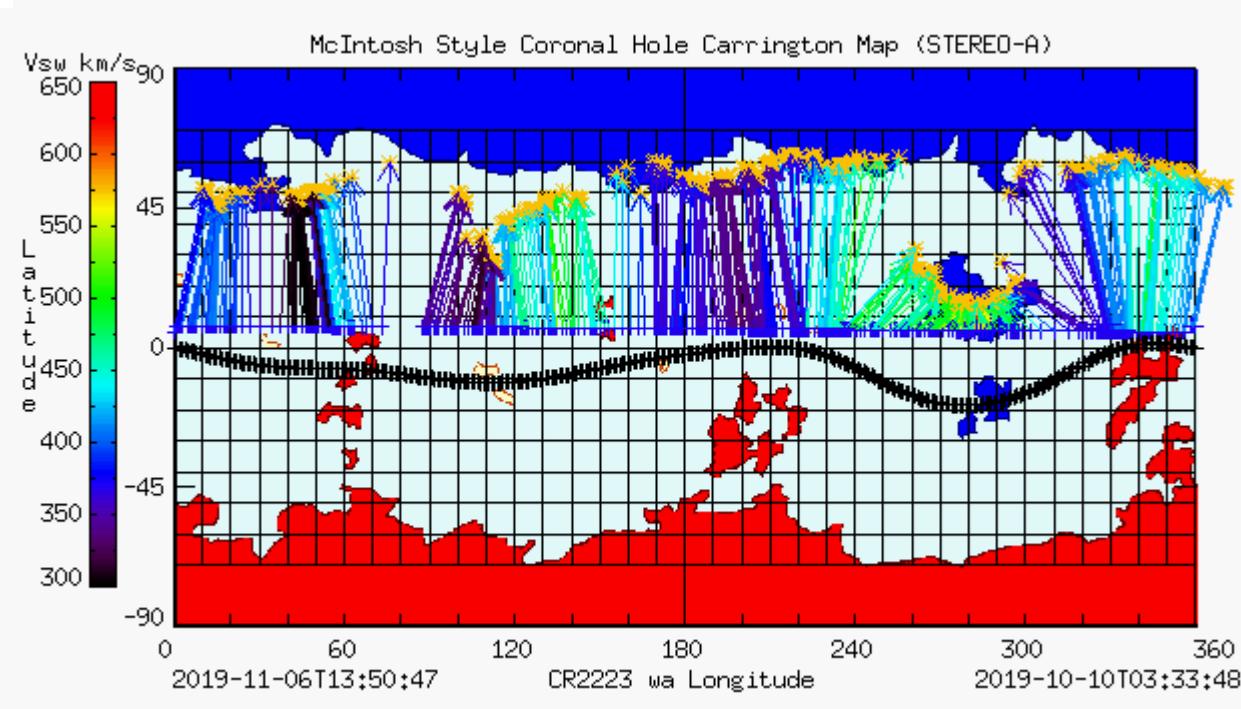
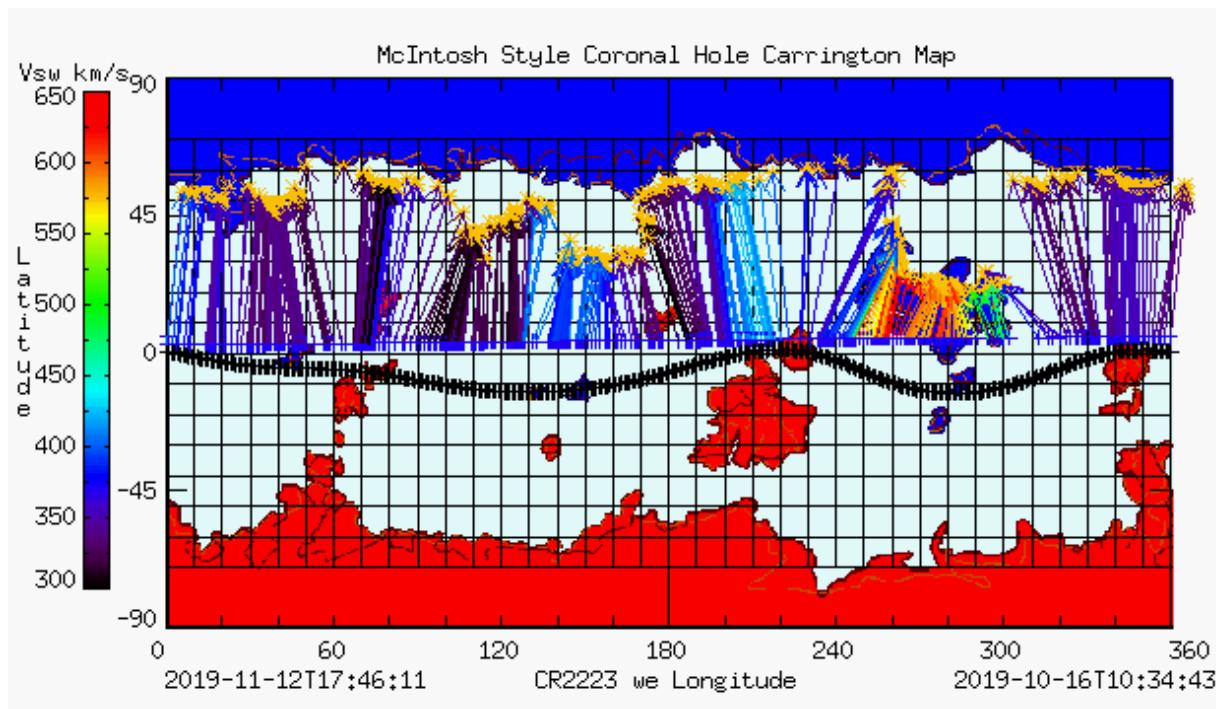


October-November 2019 Coronal Holes that lead to High-Speed Streams (HSS) of Solar Wind Velocity seen at Earth and STEREO-A.

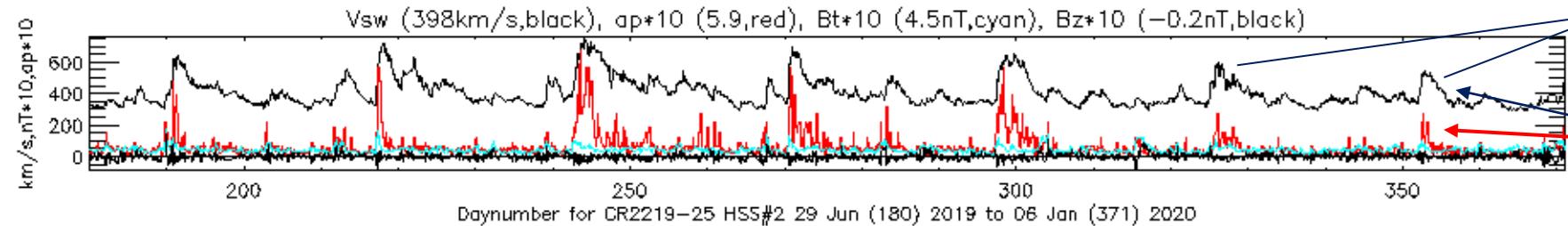
The Largest Solar Wind HSS ~ 600 km/s is in the same longitude sector as the **N+ CH** when mapped back radially from the Earth and STEREO-A to the Sun assuming constant velocity.



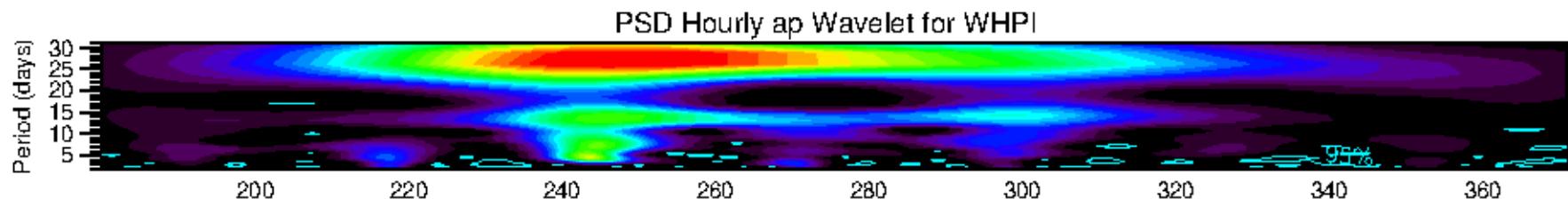
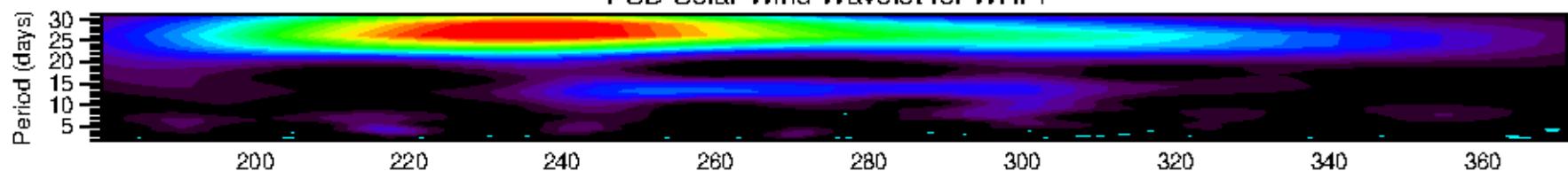
PFSS footpoints (*) from Source Surface (++) at largest velocity goes to N+CH



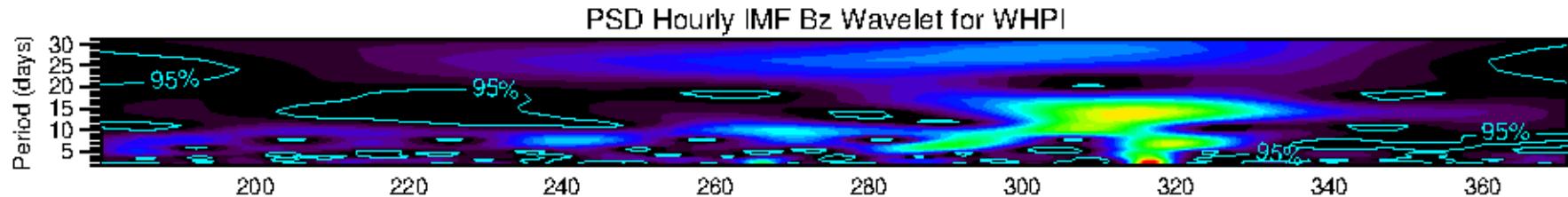
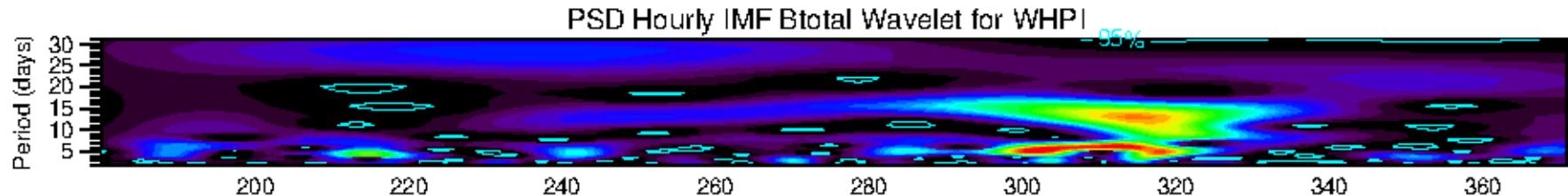
No footpoints (*) at arrow tips with color bar from the solar wind velocity) going to the S- CHs because the source surface (black +++) is all below the ecliptic plane (blue +++)



7 CRs 2219-2225
27-day periodicity in
Solar Wind and **ap**



13-day periodicity
in **ap**



June 29, 2019

Jan 6, 2020

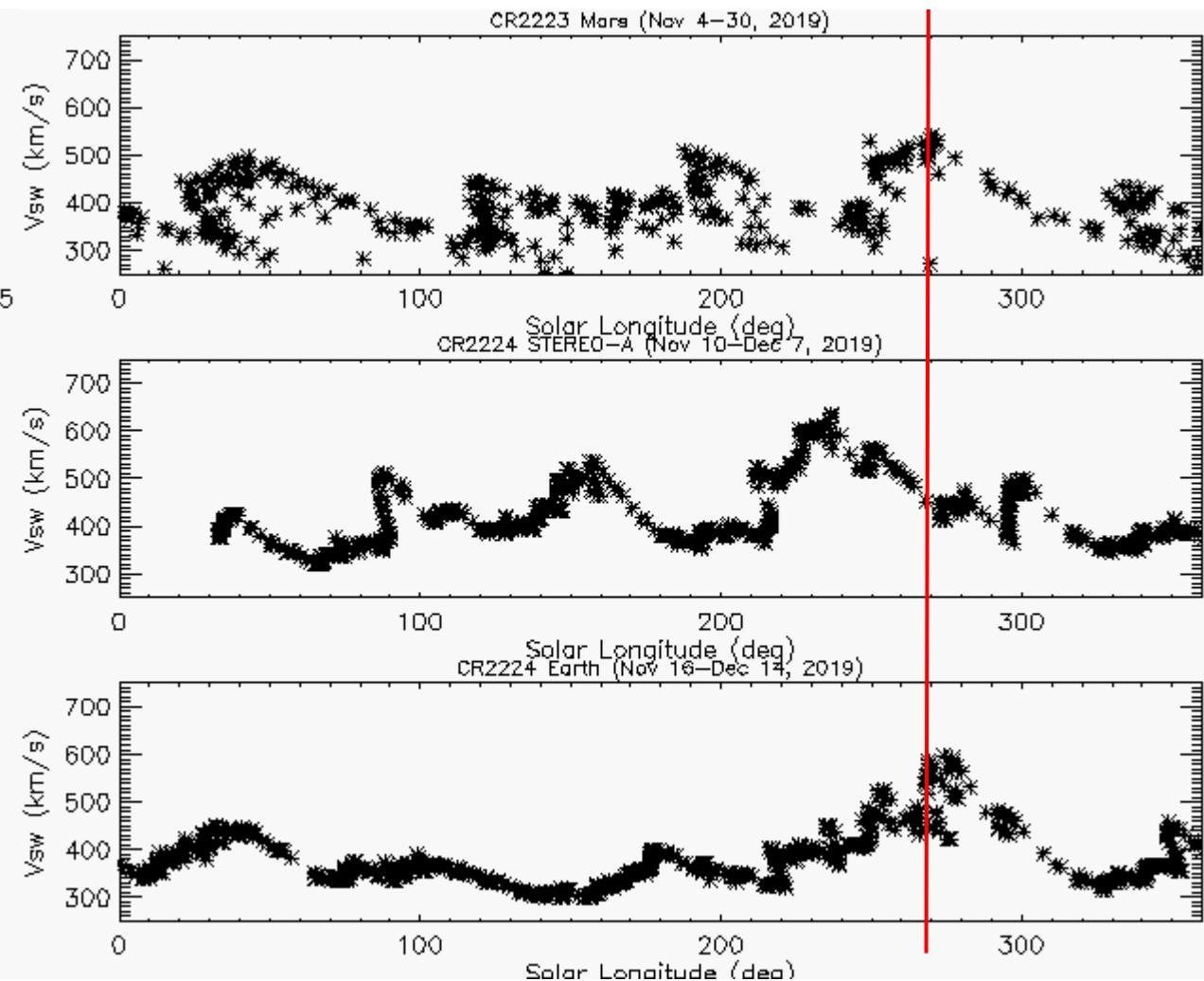
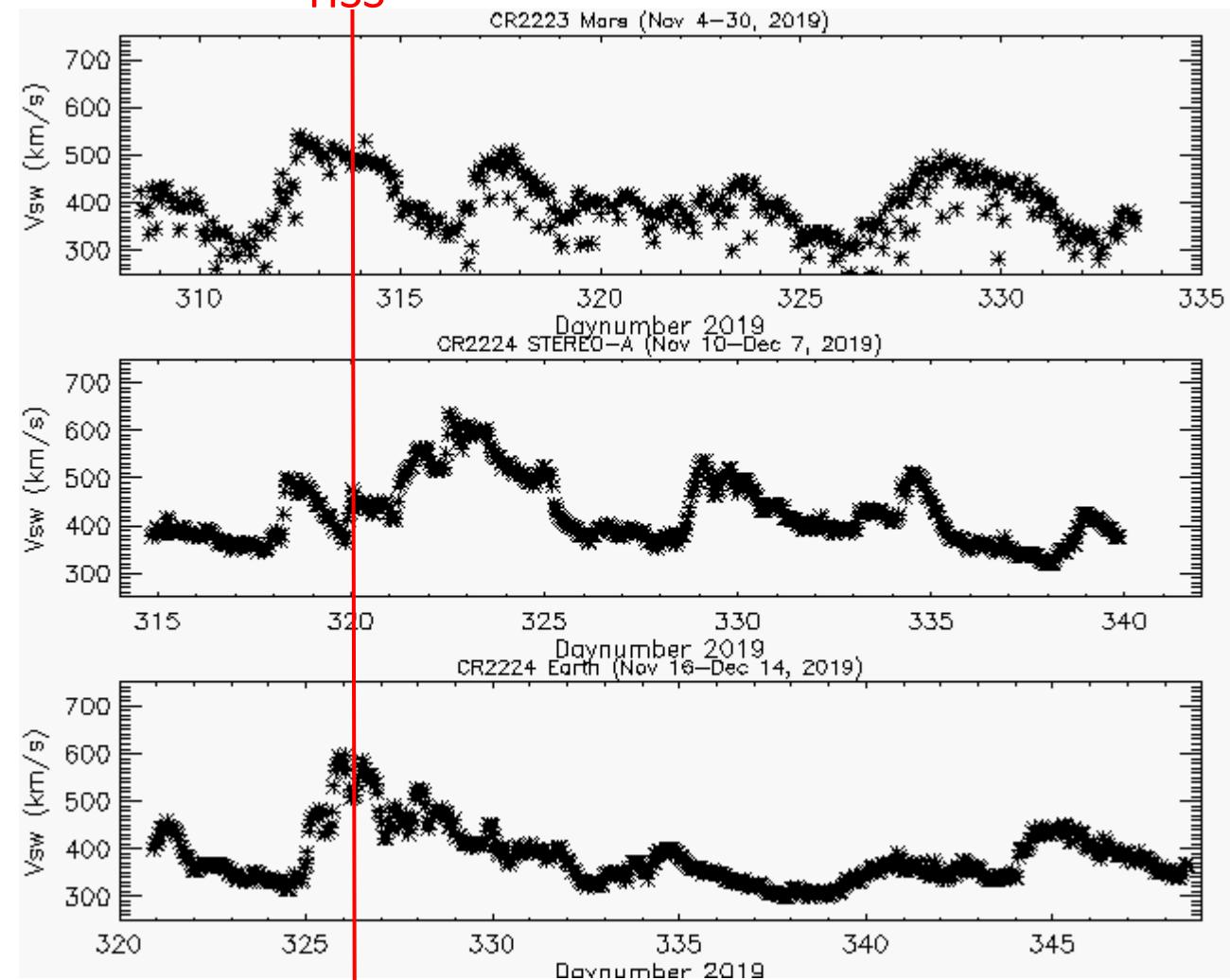
Mars Solar Wind from Maven/SWIA for CR2224(3)

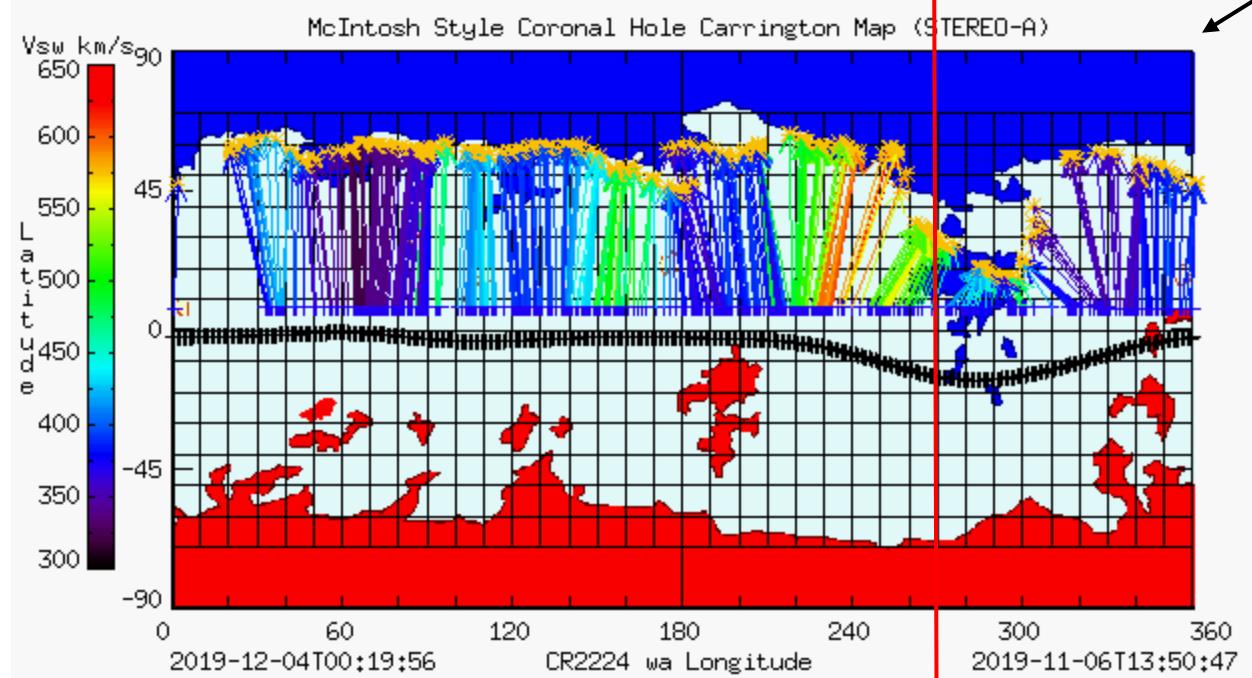
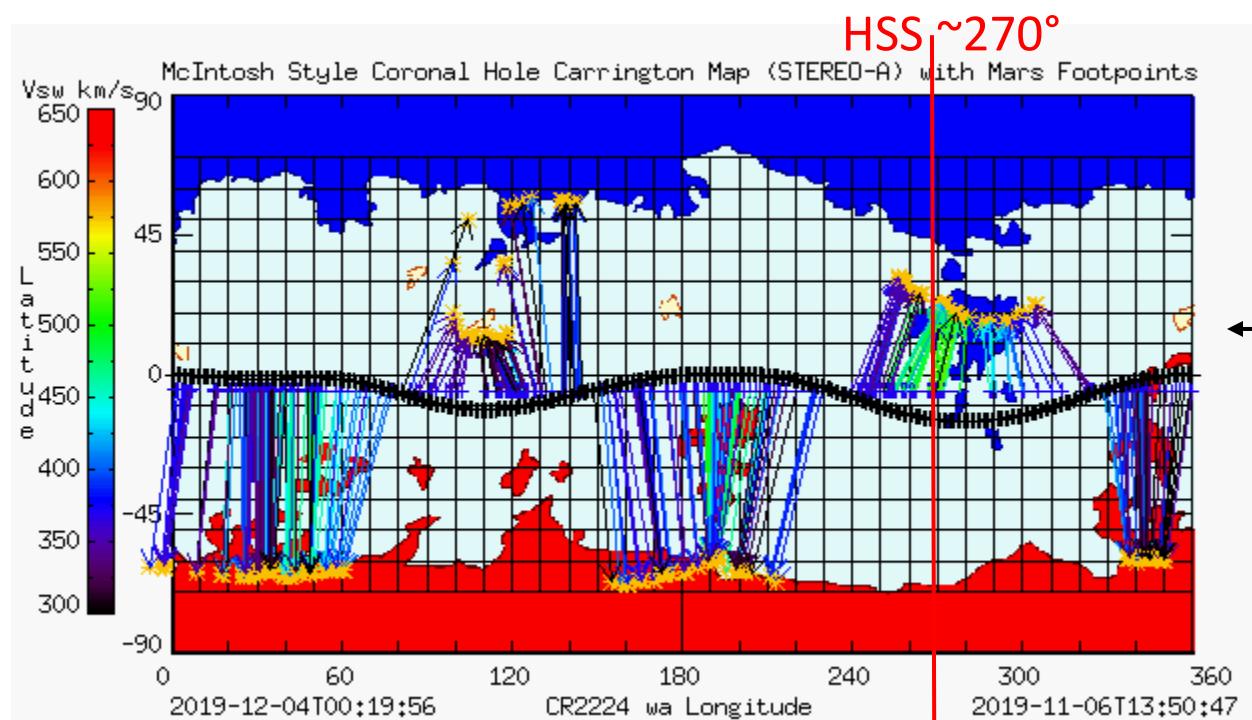
Mars is ~6 days before STEREO-A, which is ~6 days before Earth

Mapping back to the Solar Longitude

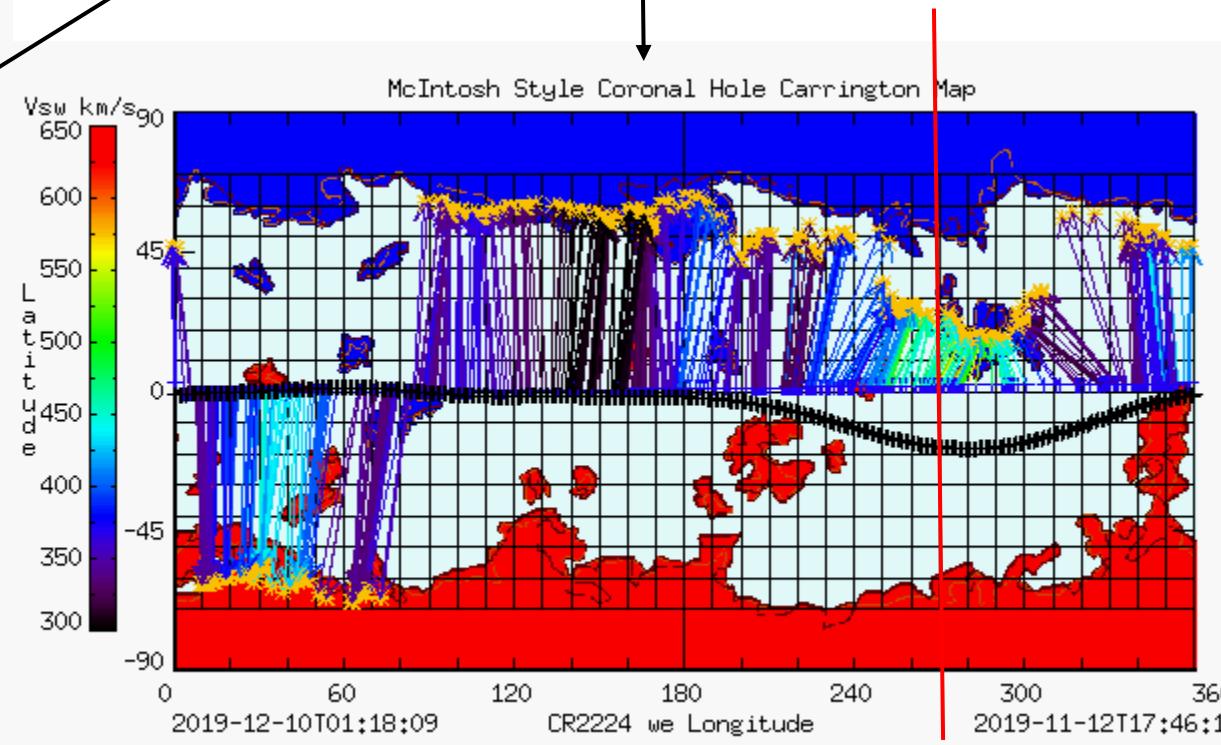
HSS at ~270°

HSS





CR2224 CH maps with PFSS footpoints (*)
from Source Surface (++) using back-
mapped solar wind from:
Mars (on STEREO-A CH map)
STEREO-A
Earth



McIntosh Style Coronal Hole (SDO/AIA) Synoptic Map

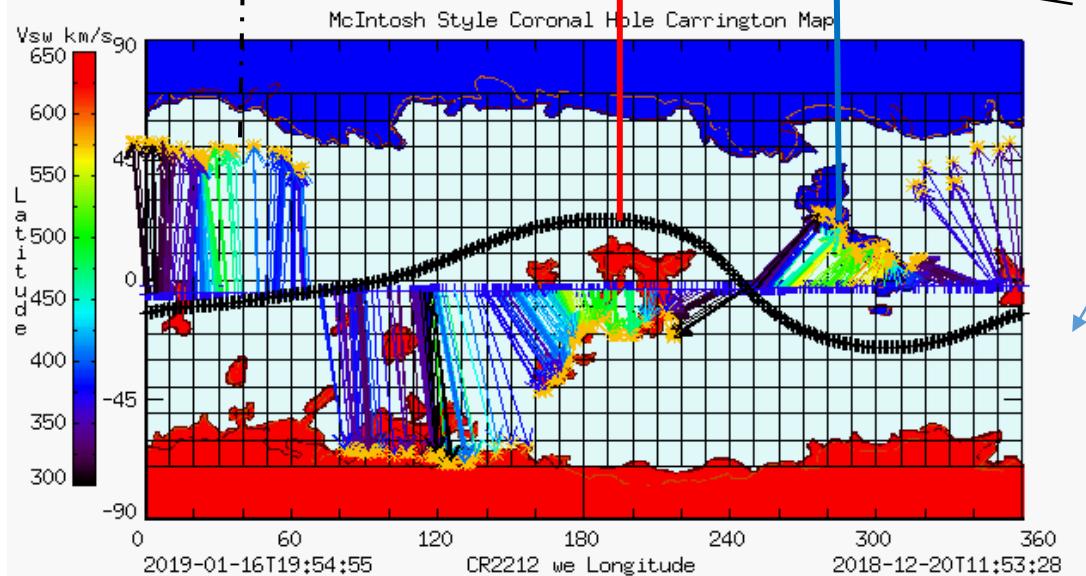
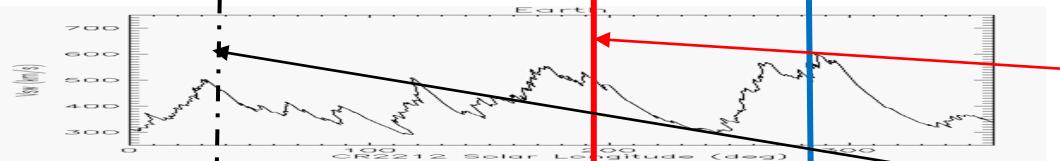
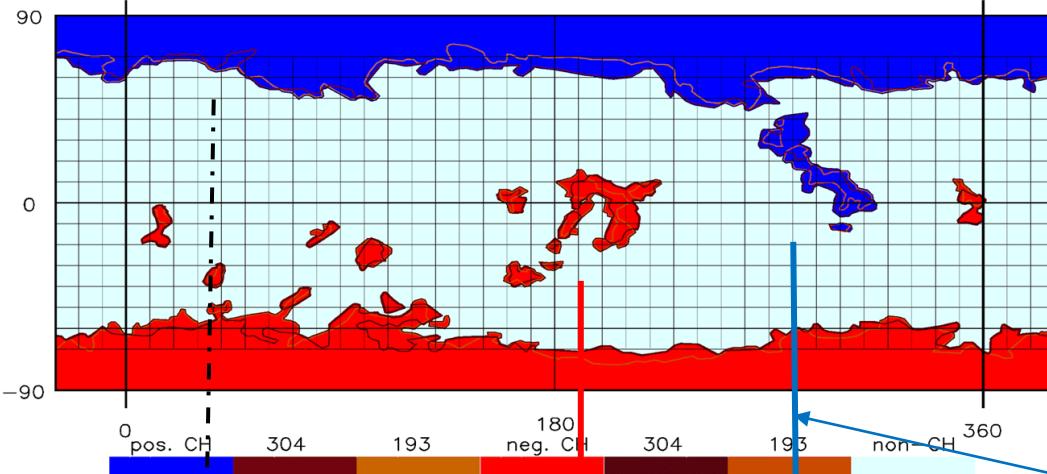
End date (longitude=0): 2019-01-16T19:54:55

B angle end date -4.69

CR2212we

Start date (longitude=360): 2018-12-20T11:53:28

B angle start date -1.57



9-day
periodicity
in HSS
Vsw from
N+ CH, S-
CH, N
pole(?) at
Earth and
ST-A

McIntosh Style Coronal Hole (STEREO-A) Synoptic Map

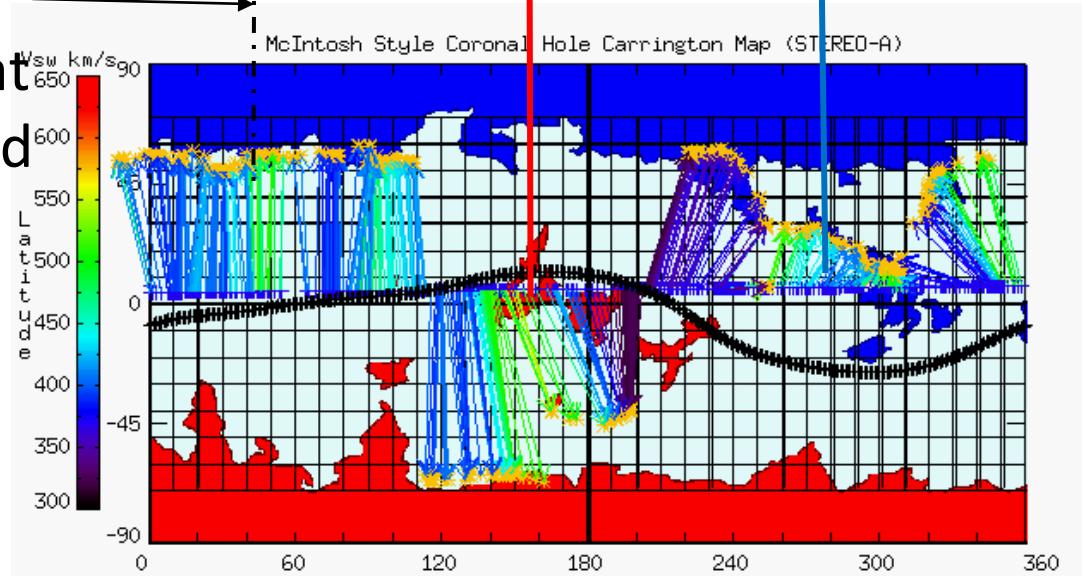
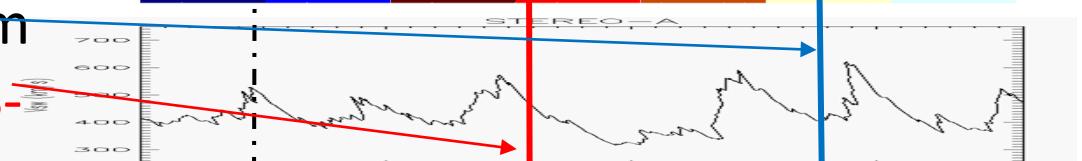
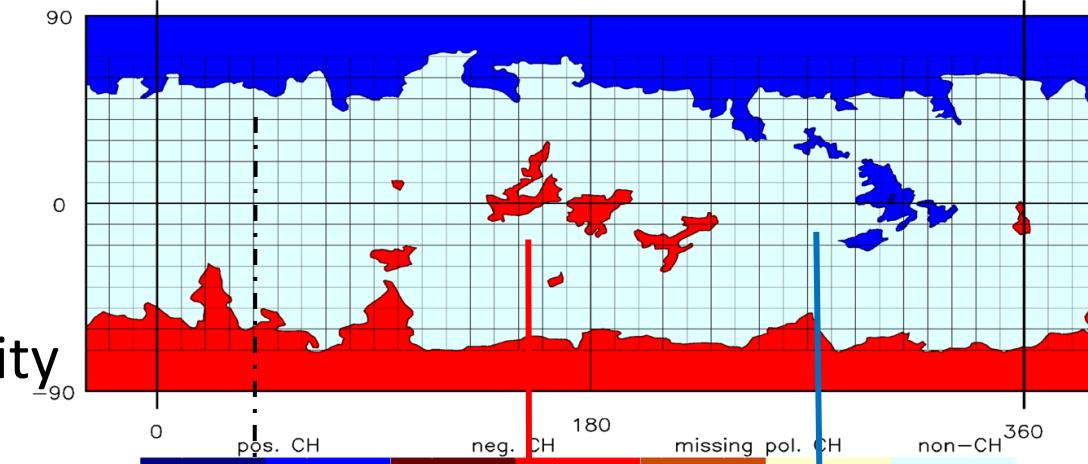
End date (longitude=0): 2019-02-05T15:51:41

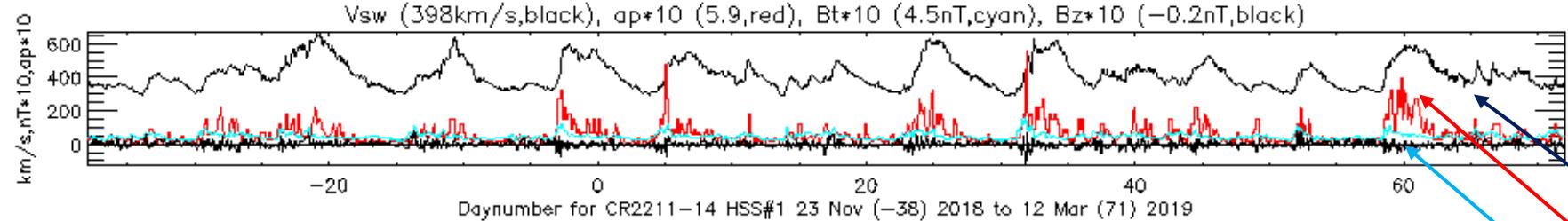
B angle end date 4.520

CR2213wa

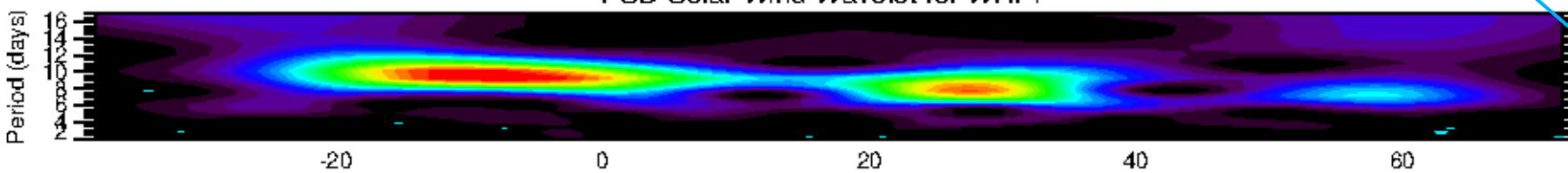
Start date (longitude=360): 2019-01-09T06:02:47

B angle start date 6.750

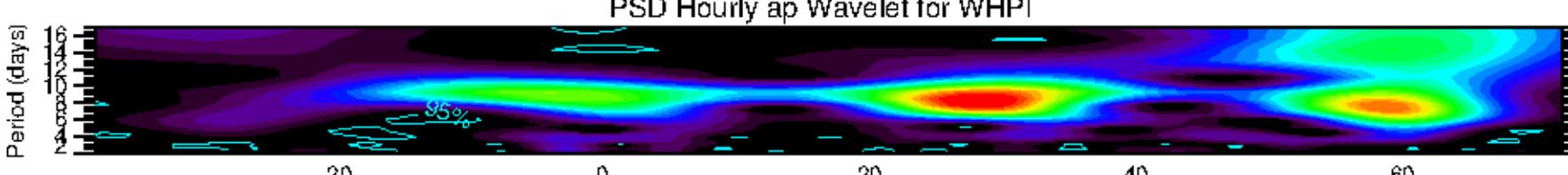




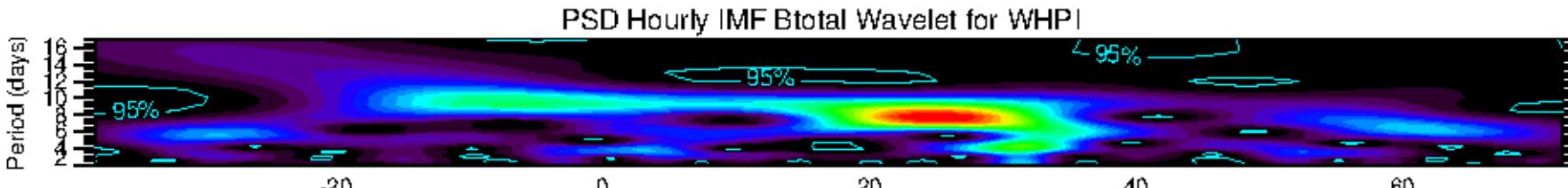
4 CRs 2211-2214



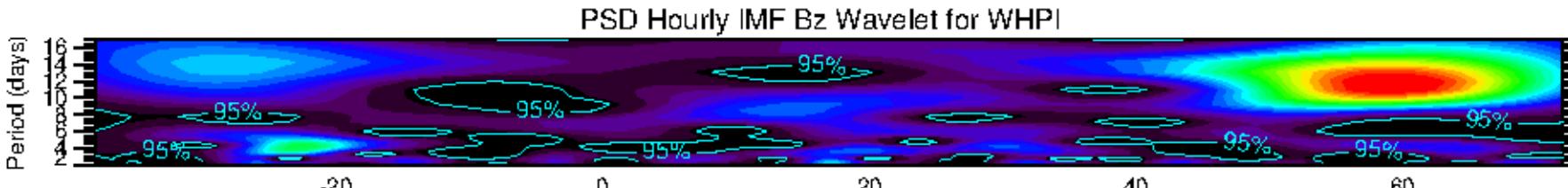
9-day periods in
solar wind



ap (+13-day at end)
IMF |B|



(27-day not shown)



Nov 23, 2018

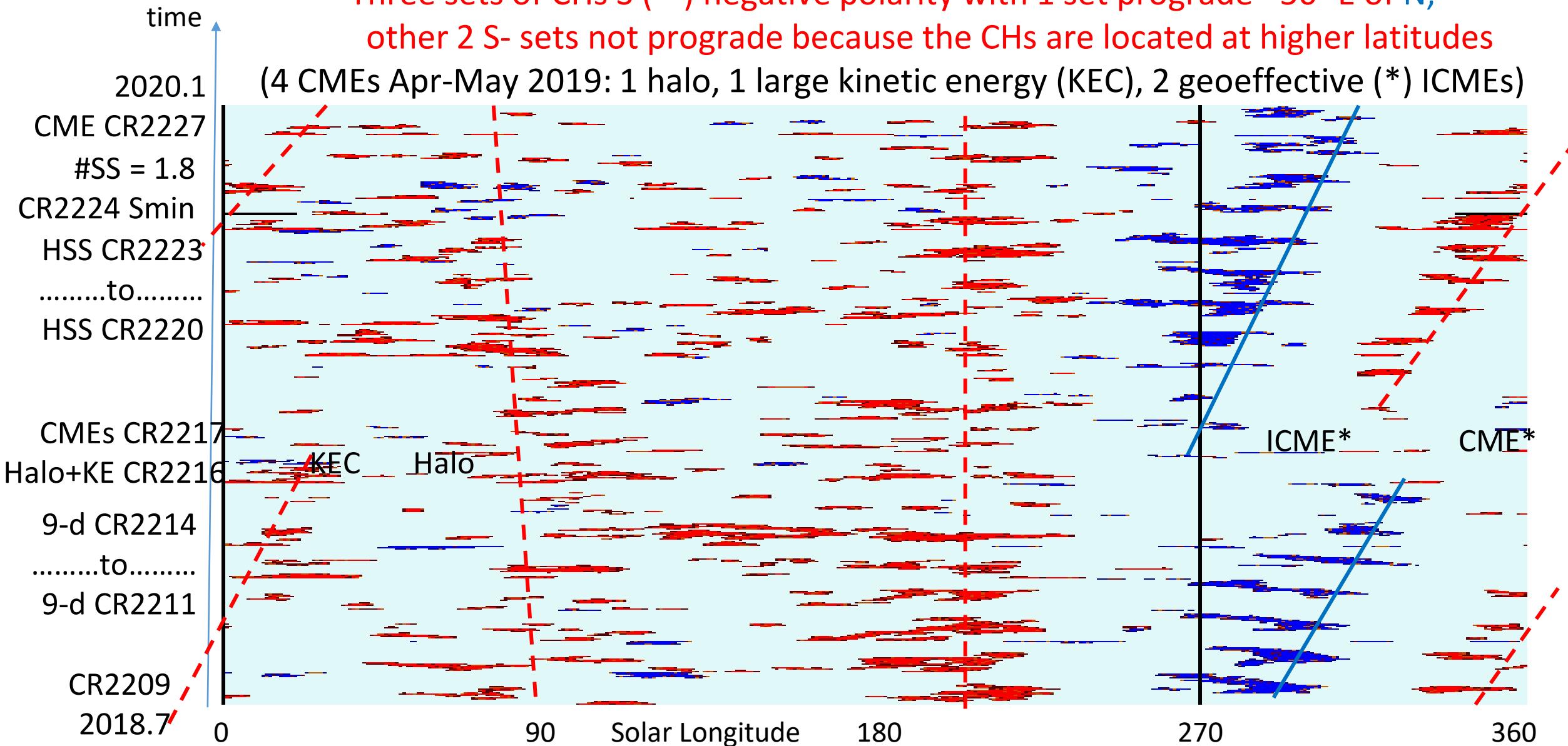
Mar 12, 2019

Solar Minimum WHPI SC 24-25 (2018.7-2020.1), N+ S- CH polarity

Largest CHs equatorial N positive polarity $\sim 270^\circ$ move $\sim 6^\circ$ /CR prograde with CME disruption

Three sets of CHs S (- -) negative polarity with 1 set prograde $\sim 50^\circ$ E of N, other 2 S- sets not prograde because the CHs are located at higher latitudes

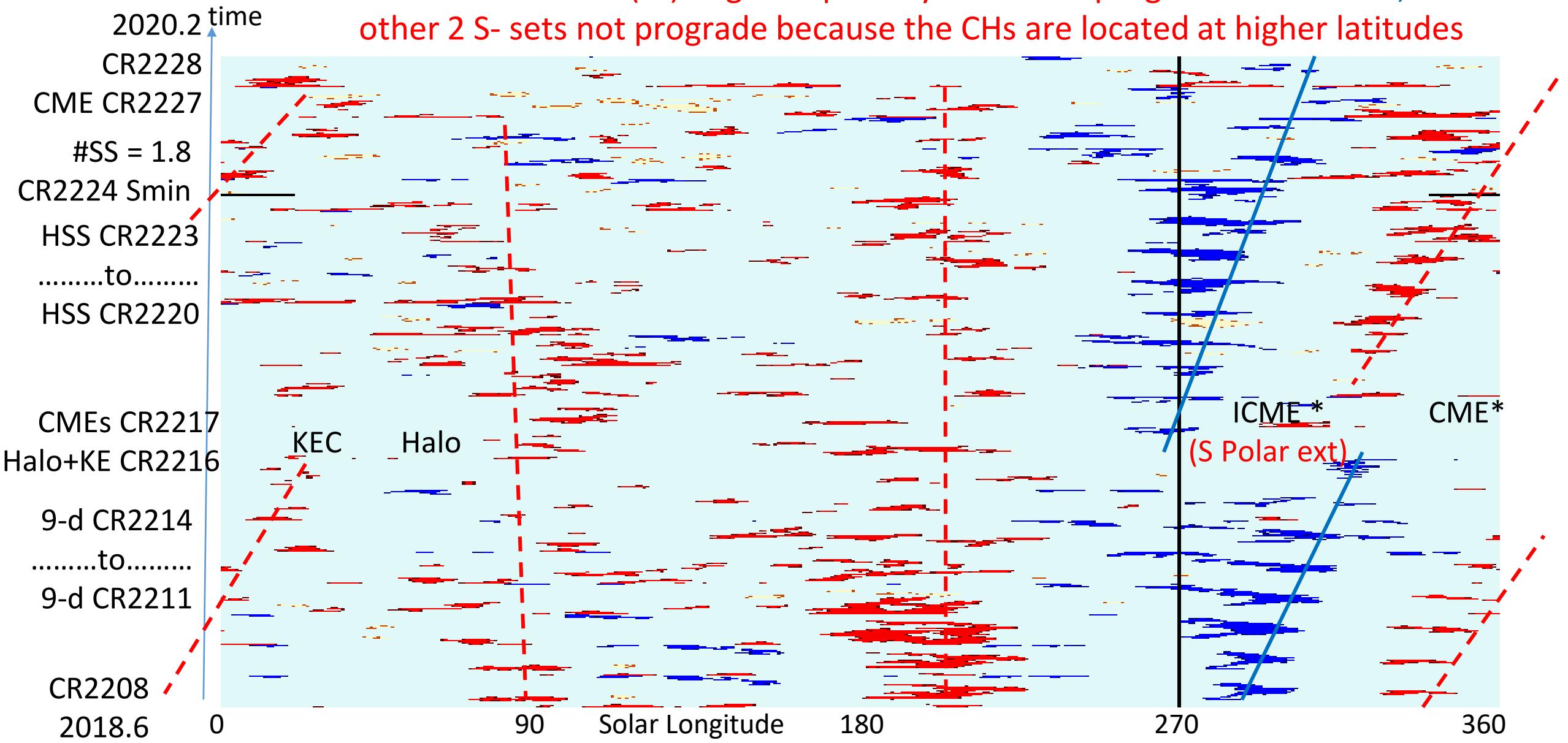
(4 CMEs Apr-May 2019: 1 halo, 1 large kinetic energy (KEC), 2 geoeffective (*) ICMEs)



STEREO-A Solar Minimum WHPI SC 24-25 (2018.6-2020.2), N+ S- CH polarity

Largest CHs equatorial N positive polarity $\sim 270^\circ$ move $\sim 6^\circ$ /CR prograde with CME disruption

Three sets of CHs S (- -) negative polarity with 1 set prograde $\sim 50^\circ$ E of N, other 2 S- sets not prograde because the CHs are located at higher latitudes



Correlations of Different Perspectives of the Solar Wind to Coronal Holes and High-Speed Streams (HSS)

- 1) STEREO-A is ~6 days Ahead of the Earth, and sees similar CHs and solar wind magnitudes.
- 2) The solar wind at Mars is outside the magneto-sheath of Mars about half the time, and shows similar HSS peaks ~6 days ahead of STEREO-A and ~12 days ahead of Earth views.
- 3) The HSS of solar wind have a strong 27-day component (mostly from the [N+ CHs moving prograde from ~270°](#)), with 9-day appearing ~CR2211-2214.
- 4) Mapbacks of the constant radial solar wind to a source surface with the Potential Field model PFSS may not always give the correct source surface location or the correct coronal hole source.
- 5) WHPI solar minimum has many low-latitude coronal holes, with 1 set of N positive polarity CHs and 3 sets of S negative polarity CHs. The N and one S set move prograde $\sim 6^\circ/\text{CR}$ since they are equatorial. The other two S CH sets are at higher southern latitudes and are approximately the Carrington rotation rate (relatively constant longitude on our maps).
- 6) CMEs can disrupt the location of the CHs so they reset at their preferred longitudes ($\sim 270^\circ$ for N) and disappear for 1-2 CRs.